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Estimation of the effect of intensive logging on ungulates (cervids) in the White River drainage

G. Schuerholz, P. McNamee and M.R.C. Massie

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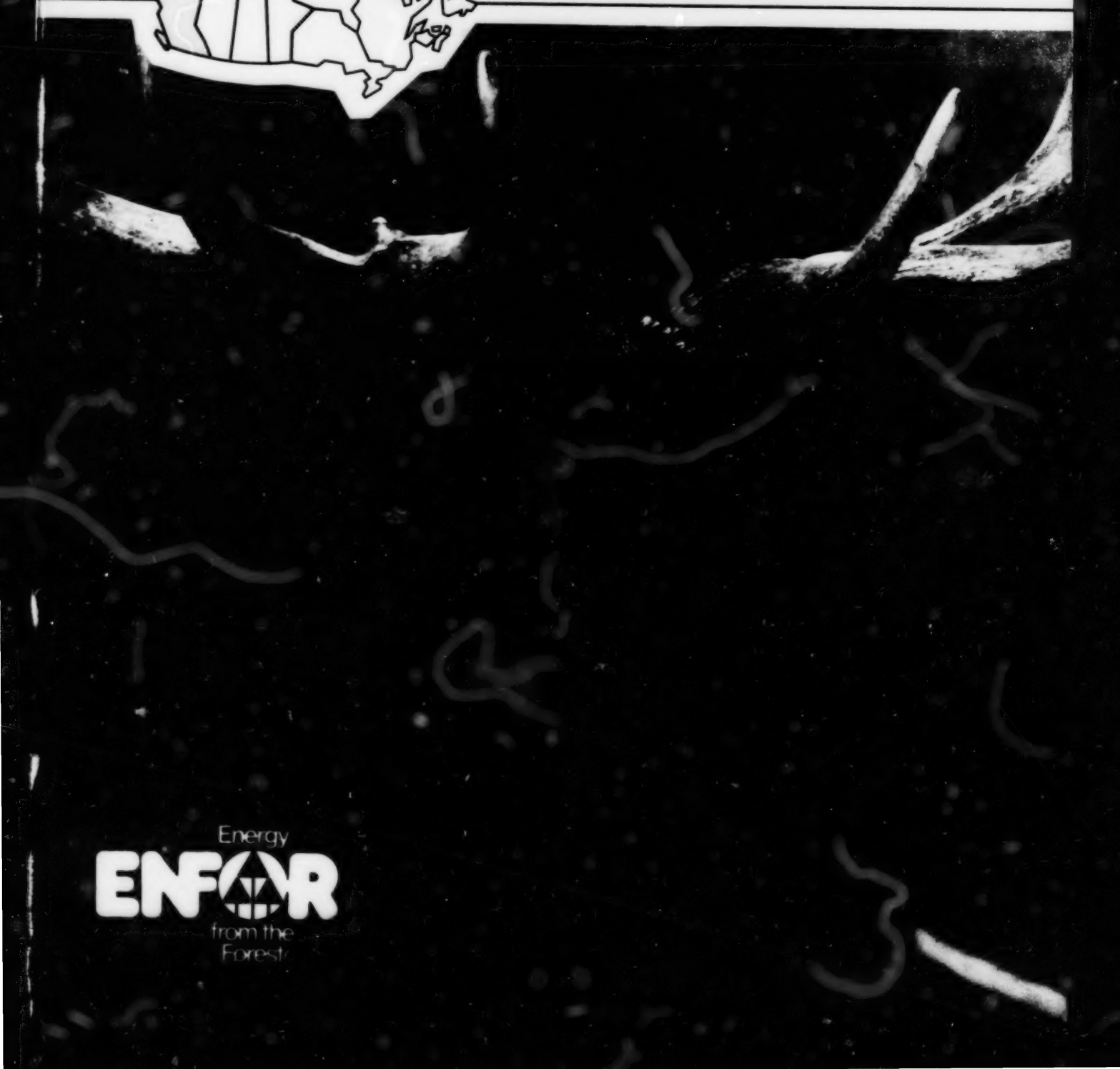

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Estimation of the effect of intensive logging on ungulates (cervids) in the White River drainage

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Foreword

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Abstract

A generalized ungulate population model was developed to estimate sustainable populations of elk, moose, and deer before and after salvage logging of beetle-damaged Lodgepole pine in the White River area of the East Kootenays. The ecosystem classification schemes of Krajina (1969) and Utzig et al. (1983) were used to describe the biogeoclimatic zones and subzones for the study area as a basis for the discussion of habitat requirements by corresponding cervid species.

Information on current forest cover was obtained from the digitized 1 : 20,000 British Columbia Forest cover maps. The data were analyzed and related to snow classes and range-specific productivity values. Biological and ecological baseline information on cervid species were taken from the literature and incorporated into the ungulate population model. Sustainable populations were calculated by species for different snow classes. Based on the results, habitat use patterns, calf-female ratios, and population densities in response to changing forest cover and environment are discussed. A brief history of ungulate management in the East Kootenays in relation to forest management is also presented.

The results show that salvage logging in the East Kootenays will significantly enhance winter ranges for elk, deer and moose.

Résumé

Les auteurs présentent un modèle généralisé des populations d'ongulés construit afin d'estimer les populations de wapitis, d'orignaux et de cerfs que peut supporter le secteur de la rivière White de la région des East Kootenays avant et après une coupe de récupération des pins tordus attaqués par des coléoptères. Ils ont utilisé les classifications de Krajina (1969) et d'Utzig et collaborateurs (1983) pour établir les caractéristiques des zones et sous-zones biogéoclimatiques du secteur étudié et ont analysé les besoins des espèces correspondantes de cervidés en matière d'habitat à la lumière de ces caractéristiques.

L'information sur le couvert forestier actuel a été tirée de cartes numérisées au 1/20 000 du couvert forestier de la Colombie-Britannique. Les données ont été analysées, et des correspondances ont été établies avec les classes d'enneigement et les indices de productivité d'emplacements particuliers. Des données biologiques et écologiques de base sur les cervidés contenues dan la littérature ont été intégrées dans le modèle. Les capacités d'hébergement ont été calculées pour chaque espèce pour différentes classes d'enneigement. Les auteurs analysent les résultats en ce qui concerne les caractéristiques d'utilisation des habitats, les rapports jeunes-femelle, la densité des populations et l'influence de modifications du couvert forestier et de l'environnement. Ils présentent également un bref historique des efforts de gestion des ongulés en rapport avec l'aménagement des forêts dans les East Kootenays.

Les résultats indiquent que la coupe de récupération améliorera de façon importante les aires hivernales d'habitat des wapitis, des cerfs et des orignaux.

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Introduction

Within the southern interior of British Columbia, significant changes have been caused in forest ecosystems through large-scale salvage operations of beetle-infested mature lodgepole pine. In this report the potential effects of the biomass removal and subsequent stand establishment on forest-dependent ungulate (cervid) species are analyzed. The study area was selected because it typified pine-beetle infestations in the East Kootenays, was ecologically diverse, provided easy access, had been subject to timber harvest, covered high-quality ungulate winter range, supported healthy populations of forest-dependent cervids, and because good baseline information was available.

Land use in the East Kootenays of British Columbia is centered around forestry, grazing, and big game hunting. Each of these uses is based on the development and maintenance of different plant communities. After logging or burning, plant succession normally proceeds from forbs and grasses to shrubs and trees. Land use can be made to follow succession through time while modifying its course only slightly. Traditional ecological concepts imply that ecosystem stability exists in those systems which are changing. A system characterized by static stability has a single equilibrium state and will return to that state along a well-defined pathway following disturbance (Botkin 1979).

Perturbations in forest ecosystems are an inherent part of their stability. They include fire, insects, disease, windthrow, and many others which ensure the system's maintenance or stability. Timber harvesting and subsequent site preparation and stand tending cause disturbances varying from mild (e.g., selective logging) to severe (e.g., permanent roads, rock cuts, etc.) which may influence system stability. Seral shrub-grasslands which establish in lower and middle elevation forests after logging are quickly replaced by coniferous trees which are established on all but the most severely damaged sites. Cervids utilize the forage which is produced on these areas during the transition from shrub-grassland to coniferous forests. Excessive grazing and browsing by wild and domestic ungulates is a perturbation which alters the composition of the shrub-grasslands and may affect system stability.

It is generally accepted that timber management and wildlife habitat management can be compatible as long as plant and animal community interactions and responses to silvicultural practices are considered (Thomas 1979).

If the objective is to grow trees, it can only be met at the cost of grass, forbs, and shrubs needed for grazing and wildlife. Similarly, if maintenance of valley bottom grasslands is required for the maintenance of cervid winter range, shrub and tree growth has to be manipulated. An increasingly popular tool which assists the land use manager in the decision-making process is the computer simulation model. It may illustrate the ecological response of a system (habitat and wildlife) to man-made changes and permit intervention by resource managers. Such a model is generally composed of a complex set of hypotheses about how the ecological systems function (expressed mostly in the form of differential equations), and a bookkeeping procedure to relate the hypothesis and to keep track of the system state as management proceeds (Walters 1971).

For this purpose a general ungulate population model was developed which predicts the changes in carrying capacity of different ungulate species in response to changes in habitat, harvest rates, and secondary disturbance.

Methods

Based on a literature review and selected interviews, the biogeoclimatic classification was described for the study area. Using British Columbia Forest Service forest cover maps, the site was analyzed according to its current cover types and corresponding potential to support ungulates. Ungulate habitats were divided into macroclasses for which suitabilities were assessed according to the potential of a type to provide the given species with food, cover, and water. For each prominent unit, pertinent habitat-enhancing parameters were identified. Based on Biophysical Ungulate Capability and Canada Land Inventory maps, the study area was stratified into ungulate-specific winter and summer ranges. Associated seasonal travel corridors were described. For deer, elk, and moose, past and current population management strategies are analyzed based on dis-

cussions with personnel of the British Columbia *Fish and Wildlife* Branch.

Supporting materials for the generalized ungulate population model were provided through literature, selected interviews, and limited field surveys. Species-specific biological information, population density estimates, and harvest rates were available through hunter return statistics. Forest cover types were analyzed based on British Columbia's digitized forest cover maps. Changes in forest cover due to biomass removal (salvage logging) following beetle kill were subjectively estimated with the digitized forest cover type maps.

The study area

Geographic location

The study area represents the beetle-infested lodgepole pine forests in southeastern British Columbia. It is partly located in the Rocky Mountain Trench but is mostly east of the trench, covering the larger part of the White River watershed from the confluence of the North White River and the main stem west. It lies approximately between latitude 50°0′ and 50°15′ N and longitude 116°15′ and 116°45′ W. Elevation ranges from 1000 to 2440 m. The total area is 55 796 ha.

Ecological characteristics

Climatic regions — This report follows Krajina's (1969) ecosystem classification which has been adapted for field use by Utzig et al. (1983). The study area is included in the Nelson Forest Region which has been subdivided into three climatic regions. Climatic regions are based on very broad climatic patterns which in the biogeoclimatic classification are expressed by vegetation sequences differing with changes in elevation (Utzig et al. 1983).

The White River study area represents the "Dry" Climatic Region which is characterized by cold and dry winters and warm and dry summers in and adjacent to the Rocky Mountain Trench (Figure 1).

Physiography and biogeoclimatic classification — The general region is characterized by a strong north-south alignment of major ridges parallel to the strike of westward-slipping thrust faults and sedimentary strata (Ryder 1981). Most of the ridges are of moderate elevation (2000 to 2500 m), with local relief of about 900 m and moder-

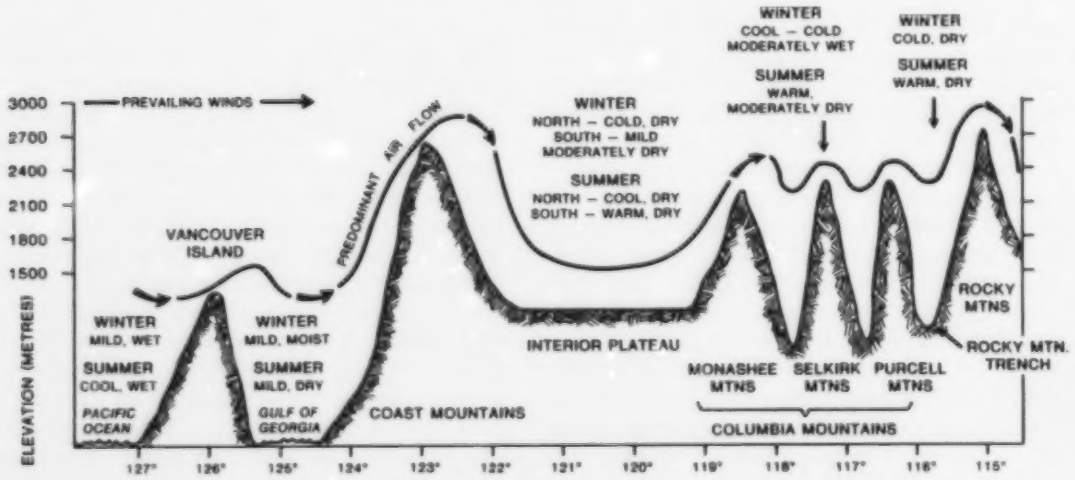


Figure 1. Latitudinal cross section of southern British Columbia illustrating the physiographic diversity and associated climatic regimes (adapted from Meidinger 1984).

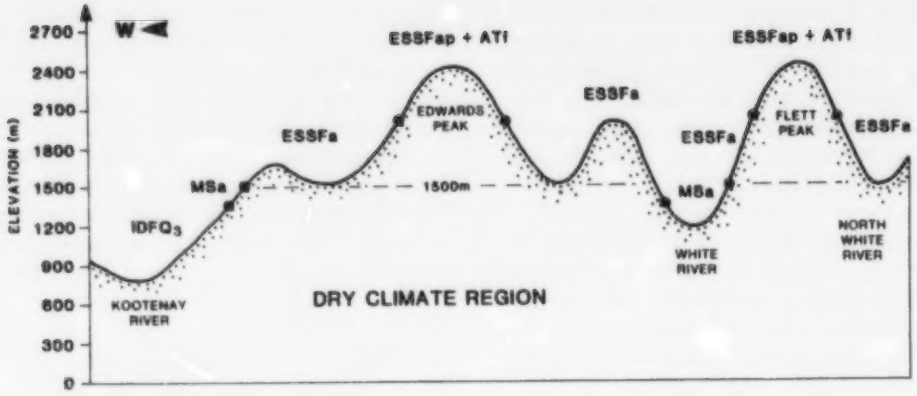


Figure 2. Biogeoclimatic profile and habitat types of the White River study area (zonification after Utzig et al. 1983).

ately steep slopes. The structurally controlled ridges have been dissected and modified by weathering and erosion. Streams occupy deep, narrow valleys which trend obliquely across the ranges. Geology, surficial materials, and soils are described by Ryder (1981).

Biogeoclimatic units are classified into zones, subzones, and variants which are based on homogeneous areas of climax vegetation communities, climate, and soil (Krajina 1969; Utzig et al. 1983).

Four biogeoclimatic zones and five subzones occur in the Dry Climatic Region of the White River study area (Figure 2).

The zones, named after dominant climax tree species are (a) Interior Douglas-fir Zone (IDF), found between 600 and 1200 m elevation, (b) the Montane Spruce Zone (MS), found between 1100 and 1520 m, (c) the Engelmann Spruce-Subalpine Fir Zone (ESSF), found between 1400 m and 2600 m, and (d) the Alpine Tundra Zone (AT), found above 2600 m. The subzones are described as follows.

i) Dry Cordilleran Interior Douglas Fir (IDFg)

This subzone is confined to the valley bottoms and lower slopes of the Rocky Mountain Trench. Douglas fir is the climax species occurring in moderately open stands. Seral stands on dry sites are composed of ponderosa pine, western larch, and lodgepole pine, which are typically open with a moderately dense shrub cover of *Purshia tridentata*, *Juniperus communis*, and *Amelanchier alnifolia*. The herb layer is dominated by *Agropyron spicatum*, and on very dry sites by *Arctostaphylos uva-ursi* mixed with *Calomagrostis rubescens*. According to Utzig et al. (1983), *Agropyron spicatum* grasslands can be found on steep south facing slopes. On moister sites, Engelmann spruce and white spruce may be co-dominant. In seral stands, ponderosa pine is replaced by seral aspen. Shrub layers are generally dense and characterized by *Cornus sericea*, *Symphoricarpos albus*, and *Mahonia aquifolium*. The herb layer is composed of *Linnaea borealis*, *Smilacina stellate*, and *Equisetum arvense* growing mostly on Gleysols. Seral stands are common as a result of widespread wildfires which have spaced and thinned the forests. Fires have eliminated younger germinants on many sites, rejuvenating shrubs and grasses. Exclusion of wildfire over the past three decades has resulted in increasing crown closure and subsequent loss in shrub and herb production.

The combination of very light snowfall and high-quality browse production in this subzone provides elk and deer with some of the best winter ranges in British Columbia. (As will be discussed in a different context, some

areas in this subzone have been over-utilized by livestock and wild ungulates. Overbrowsing and absence of fire have caused scarcity of the yellow-stem *Ceonothus* shrub, which is a highly important browse species and serves a significant nitrogen-fixing role in this system.)

The most prominent plant associations in this subzone are (a) *Purshia-Arctostaphylos*, (b) *Agropyron-Crepis*, (c) *Spiraea-Calamagrostis*, (d) *Symphoricarpos-Linnaea*, (e) *Cornus-Cornus* (f) *Betula-Equisetum*, and (g) *Distichlis-Hordeum*. Corresponding species are listed by Utzig et al. (1983, p.33).

ii) Dry Southern Cordilleran Montane Spruce (MSa)

This subzone is mostly found on arid slopes in the Rocky Mountain Trench and lower slopes of the mountains between the Kootenay and North-White Rivers. Climax tree species are Engelmann spruce and balsam fir. Western larch and lodgepole pine are the major seral species. The shrub layer is represented by *Lonicera utahensis*, *Spireae betulifolia*, and *Menziesia ferruginea*. On dry sites the prominent shrub species are *Shepherdia canadensis* and *Amelanchier alnifolia*, whereas on moister sites *Rosa acicularis*, *Symphoricarpos albus*, and *Cornus sericea* predominate. Herbs on dry sites are represented by *Linnaea borealis* and *Calamagrostis rubescens* frequently mixed with *Arctostaphylos uva-ursi* and *Pleurozxium schreberi* on Brunisolic Grey Luvisols. On moister sites *Equisetum arvense* and *Cornus canadensis* are common on Gleysols.

The most common associations of this subzone are (a) *Agropyron-Heucherea*, (b) *Juniperus-Arctostaphylos*, (c) *Shepherdia-Calamagrostis*, (d) *Menziesia-Aster*, (e) *Symphoricarpos-Thalictrum*, (f) *Lonicera-Equisetum*, and (g) *Betula-Carex*. The corresponding plant species are listed by Utzig et al. (1983, p.37).

Winters in this subzone are extremely cold but have a slight snowfall. This subzone ranks as a relatively important elk and deer range, which serves cervids principally in late fall, early winter, and early spring during seasonal migrations. Only in mild winters is this area used by cervids. This subzone is characterized by lodgepole pine dominated stands reaching maturity. Some stands, particularly those with high stem density have succumbed to mountain pine beetle attack. Many of the affected areas have been logged, others have been excluded from logging due to lack of access. Many stands are vulnerable to insect damage.

iii) Dry Southern Cordilleran Forested Engelmann Spruce-Subalpine Fir (ESSFa).

Approximately two-thirds of the study area is occupied by this subzone which typifies the upper slopes. Subalpine fir and Engelmann spruce are the zonal climax species with lodgepole pine and occasionally Douglas fir as seral species. Shrub layers are generally not as well developed as in other ESSF subzones. They are represented by *Shepherdia canadensis* and *Juniperus communis* on dry sites, and by *Lonicera involucrata* and *Menziesia ferruginea* on wet sites. The herb layer is poorly developed. On wet sites it is dominated by *Equisetum arvense* and *Thalictrum occidentale* and on dry sites by *Calamagrostis rubescens*, *Linnaea borealis*, *Arnica cordifolia*, and *Vaccinium myrtilus*, growing on Brunisols.

Utzig et al. (1983) have noted that lodgepole pine in this subzone is abundant as a result of widespread fires.

The most common associations listed by Utzig et al. (1983) are: (a) *Juniperus-Calamagrostis*, (b) *Shepherdia-Arnica*, (c) *Rhododendron-Vaccinium*, (d) *Menziesia-Orthilla*, (e) *Lonicera-Equisetum*, and (f) *Salix-Carex*.

This subzone provides most of the summer range to the cervids in the study area. It is used by moose, mule deer, and elk. Summer range quality is determined mostly by the availability of palatable herbaceous growth in the vicinity of cover and water. The summers in this subzone are cool and moist and in winter snow depth is limiting to cervids except for steep, southern slopes.

iv) Dry Southern Cordilleran Parkland Engelmann Spruce-Subalpine Fir (ESSFap).

This subzone links the treeless Alpine Tundra and the higher elevation Engelmann Spruce-Subalpine Fir subzones, ranging from about 2130 m to 2600 m in elevation. High winds and temperature fluctuations influence stand establishment, although climatic conditions tend to be less pronounced than on Alpine Tundra sites.

Climax species are Engelmann spruce, whitebark pine, subalpine fir, and alpine larch. The canopy is generally sparse (1 to 15%). The frequently well developed shrub layer is dominated by *Vaccinium scoparium*, and the generally poorly established herb layer is represented by *Solidago multiradiata*, *Antennaria racemosa*, *Poa alpina*, and *Festuca scabrella*. Most associations in this subzone represent young to seral stages transitional between meadow and forest, and include Krummholz stands. The rate of succession is probably very slow due to wind and temperature extremes (TAESCO 1985a).

Fire and grazing by wild ungulates may maintain these communities in early seral stages. Prominent associations in this subzone are: (a) *Pinus albicaulis-Vaccinium scoparium* – Forest Transition, (b) *Sedum-Heucherea* – Steep Slope, and (c) *Pinus albicaulis-Rhododendron* – Upper Slope. Most of the subalpine associations provide ungulates with good-quality summer range. Large amounts of meadow-forest edge are typical. The herb and epiphyte layers are diverse and have a high productivity (TAESCO 1985b, 1985c). Successional trends are complex and reflect the interactions of site and environmental parameters in combination with fire and ungulate grazing. As a result, many of the Meadow-Parkland communities which appear to be pre-seral or early seral stages of Engelmann Spruce-Subalpine Fir climax may, in fact, be climax communities maintained by fire and grazing.

v) Dry Southern Cordilleran Alpine Tundra (ATf)

This subzone is restricted to the high-elevation ridge tops above 2600 m. Environmental conditions are harsh with high winds and extreme temperature fluctuations. Slopes are often steep; dry rocky sites contribute to creating a desiccating environment. Sites range from diverse, high-biomass herb, grass, and forbacious communities, to low-biomass, dry, shrub-dominated associations. Most of the communities appear to be climatic climax.

Although this subzone can be of significant importance to wintering ungulates (goats and sheep) and as ungulate summer range, it is of low importance to forestry. Cervid-forest interaction is confined to the adjacent ESSFap subzone which provides ungulates with climatic shelter and cover.

Computerized forest cover data

The digitized forest cover maps of British Columbia's Ministry of Forests (1983) were used to quantify and qualify information on each forest block in the study area. This information was assembled on a computerized spreadsheet. Each row of information in the spreadsheet (approximately 47 columns) represents a unique area on a forest cover map and gives pertinent actual or coded descriptions for land (ha) in the block. As all landforms are specified (i.e. water, rock, swamps, alpine areas, etc.) and assigned a block number, each of the three blocks in the study area has total area control (i.e. the sum of hectares for all block numbers will equal the total hectares in the study area). The unique advantage of using a computerized spreadsheet is that any combination of forest cover type can be rapidly calculated for different canopy or density classes or stand age compositions by slope, aspect, and elevation. This provides a powerful tool for simulating conditions of interest for the assessment of forest and cervid interactions.

The forest blocks of the digitized forest cover maps do not correspond with the ecosystem classification of Krajina's (1969) and Utzig et al. (1983) which frequently are used to describe wildlife habitats. It was therefore necessary to define a habitat "denominator" which correlates biogeoclimatic subzones and forest cover types. Elevation was chosen as the common denominator. Five habitat types for cervids were arbitrarily

Table 1. Distribution of habitat type (ha) in White River study area

Habitat type	Deer and elk winter	Moose winter*	Summer	Total[1]
Non Usable[2]	224	105	11 920	12 144
Alluvial	0	0	0	0
Lowland	3135	0	2057	5192
Upland	2402	4428	21 564	23 966
Montane	224	0	14 270	14 494
Total	5985	4533	49 811	55 796

[1] Moose winter range overlaps that of deer and elk; and so is not included in the total.
[2] Non Usable for commercial forestry. Mostly alpine and slide areas.

differentiated as (a) alluvial forest, (b) lowland forest, (c) upland forest, (d) montane forest, and (e) alpine. Figure 2 shows the relationship between habitat types and subzones, and Table 1 the relative abundance of the habitat types. The habitat category nonusable (Table 1) refers to its value to support "commercial forests" only. Nonusable land is mostly composed of Alpine Tundra and slides which can provide cervids with high-quality summer range. Except for caribou, which occasionally may be found in alpine areas by late winter, the Alpine Tundra is not used by cervids as winter range.

The category "brush" occurring on the forest cover maps is explained as follows. It covers (a) "non-productive forests" (N.P.), and (b) "non-commercial forests" (N.C.), on "disturbed sites, where stocking is doubtful" (D.S.D.), and on sites "not satisfactorily restocked" (N.S.R.). "non productive forests" are found on land classed as "not forest land," or on "very poor site forest land." In the latter case, conifers may be present but are "stunted" or "branchy"; these conifers are usually mixed with hardwoods, frequently forming over-aged, open stands.

On "not forest land," the brush designation usually refers to some hardwoods mixed with stands of low growth with very low cover. Conifers are absent in this category.

"Non-commercial" brushlands may be found on forest land that is not stocked with conifers. The usually dense, high crown closure brush cover can be composed of willow, alder, or dogwood mixed with lower growing shrubs. "Non-commercial" brush may also refer to forest land on which plantation or regeneration failed and brush took over. In this type, a minor conifer component may be present. It usually provides excellent forage for cervids as it is the result of N.S.R. or D.S.D. The relationships are explained in Table 2.

Range designation for cervids

It is commonly accepted that winter range in high snowfall areas is limiting to cervids, and that summer range is abundant. In this light, the winter ranges in the study area were identified based on Canada Land Inventory ungulate capability maps and information provided through the Cranbrook regional office of the British Columbia Fish and Wildlife Branch.

Deer and elk in the study area share the same winter range. The highest quality winter range (Class 1 and 2) is located in the floodplain of the Kootenay River and along the adjacent eastern terraces (Figure 3). Class 2 elk and deer winter range is found on south facing slopes west of White Swan Lake. Moose and elk winter range overlap in the White River watershed, although moose frequently may be found in the montane

Table 2. Allocation of categories:
(a) disturbed, stocking doubtful, (b) not satisfactorily stocked, (c) non productive forest, and (d) non commercial forest (typical examples for the White River study area).

Crown Closure	No Conifer Stand or Cut Overstory	Young Overstory (Age 1-20)	Medium Overstory (Age 20-40)	Mature Overstory (Age over 40)
Nil Canopy (0-5%)	All D.S.D. + 70% N.S.R. 15% N.P. 50% N.C.	25% N.S.R.	5% N.S.R.	
Light Canopy (6-25%)	N.C. — 50%			N.P. — 80%
Medium Canopy (26-55%)				N.P. — 5%
Heavy Canopy (>55%)				

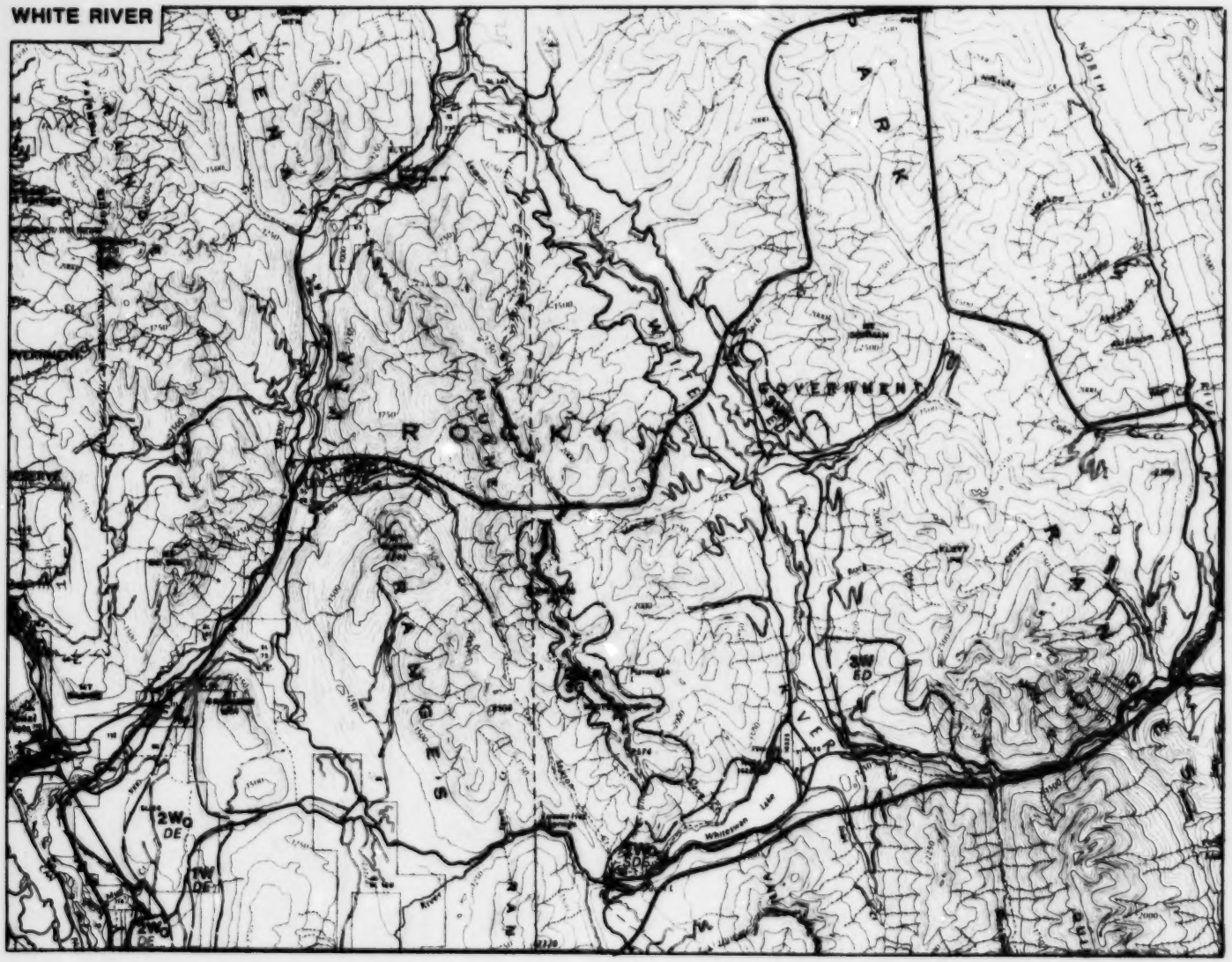
parkland forests with southern exposure (Demarchi et al. 1984).

Most of the White River study area may be used by deer, elk, and moose in summer. Summer range quality is generally low except for logged and slide areas, and moist upland and lowland forests with good quality browse. Cervids summering in the North-White River watershed, mostly use the river floodplain and adjacent lower wooded slopes for their seasonal movements (Figure 3). Approximately 10% of the White River study area is designated deer and elk winter range and 8% is designated as moose winter range (Table 1). Approximately 52% of elk and deer winter range is located in lowland forest, and 40% in the upland forest. Moose range concentrates on Upland and Montane habitats.

Stand closure and age class distribution

Of the deer and elk winter range, 58% is comprised of mature forests with medium-to-heavy canopy, 22% of mature stands with light canopy, and 5% of medium aged stands with medium crown closure. Cut or young stands without canopy occupy approximately 11%, and 4% is not useable (Table 3). On elk and deer summer range 55% of the total area is covered by mature stands with medium to heavy canopy, 7% by mature stands with light canopy, and 12% on cut or young stands without canopy. Five percent is not useable. Alpine tundra covers 18% of the summer range and 3% is designated to slides. Slide areas, which are mostly composed of avalanche chutes, provide all cervid species in the study area with high-quality late spring to fall range.

Of the deer and elk winter range, approximately 1244 ha of mature lodgepole pine are infested by beetles, of which 806 ha will be converted to other types and 438 ha salvage logged. Of the beetle-infested 10 000 ha of lodgepole pine on the summer range, 2500 ha will be converted to other types and 7500 will be salvage logged. The criteria used for conversion or salvage are that all stands on the winter range with a significant component of immature Douglas-fir will be converted to Douglas-fir, and all mature pure pine



LEGEND

example:

$3W^{R}_{Q}$ *SDEG*

1 Class 1 lands have no significant limitations to the production of ungulates

2 Class 2 lands have very slight limitations to the production of ungulates

3 Class 3 lands have slight limitations to the production of ungulates

R Land subclass indicating restricted depth of rooting zone

Q Climate subclass indicating excessive snow depth as a limitation to ungulate mobility and food availability

S Mountain sheep

D Deer

E Elk

G Mountain goat

0 5km

Figure 3.

Ungulate winter ranges in the White River study area.

Table 3. Stand age and crown closure distribution for elk and deer seasonal ranges in the White River study area (ha)

Age class	Crown closure	Winter range		Summer range	
		Current	After salvage	Current	After salvage
Non forest – alpine	–	–	–	9172	9172
Non forest – other	–	224	224	2748	2748
Cut or nil overstory	Nil canopy	295	733	1751	9251
Young overstory (1-20 years)	Nil canopy	367	367	4026	4026
	Light canopy	–	–	574	574
	Medium canopy	–	–	10	10
Medium overstory (21-40 years)	Nil canopy	10	10	2	2
	Light canopy	194	194	215	215
	Medium canopy	80	80	113	113
	Heavy canopy	–	–	51	51
Mature overstory (41+ years)	Nil canopy	–	–	64	64
	Light canopy	1325	2131	3276	5776
	Medium canopy	2688	2193	21 400	17 379
	Heavy canopy	802	53	6409	430
	Totals	5985	5985	49 811	49 811
Total winter and summer range		55 796			

would be salvage logged. On the summer range all mature pure pine stands older than 80 years would be salvage logged or burned, or both; of these 50% would revert to second species. After salvage logging the "cut or young" stands without canopy would increase on the deer and elk winter range by approximately 7% and on the mature stands with light canopy by 60%. Mature stands with medium to heavy canopy would decrease by 35%.

Moose winter range in the White River study area overlaps with elk and deer winter range, although it mostly concentrates on upland habitats. Approximately 4428 ha of forest land is designated moose winter range. It is characterized by cut overstory or young stands (1 to 20 years without canopy). It is located in the upland habitat. A minor portion is montane habitats with south and southeast exposures. The winter range also includes early seral successions. Some 4444 ha have a potential for new moose winter range. In mature stands or stands over 40 years old with medium to heavy canopy, 1709 ha are beetle-killed and will be salvaged or burned. An additional 544 ha of mature forests with open canopy will be created in stands in which beetles killed the pine and where the fir or larch component of the stand survived. This would create approximately 2253 ha of new moose winter range.

The generalized ungulate population model

Scope of the model

The purpose of this model is to predict the changes in carrying capacity of different ungulate species in response to changes in habitat, hunting rates, and secondary disturbance. The model is adapted to (a) deer, (b) elk, and (c) moose.

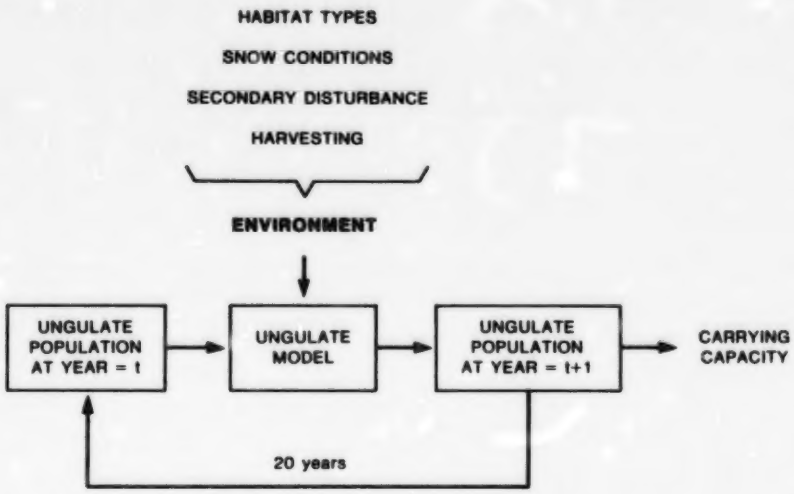


Figure 4. Structure of the generalized ungulate population model. The model predicts the carrying capacity for a particular ungulate species given the nature of the environment defined by the user.

These different species use and prefer different habitat types, and have different responses to weather conditions. In order to make the modelling tractable, the model has been made sufficiently general so that the functional relationships do not have to change from species to species or habitat to habitat. Therefore, the structure of the model is based on general, well-used ecological relationships which define the interactions between animals and their environment. The parameters describing these relationships can then be varied depending on the ungulate species of interest so that a species-specific model is defined. Several major ecological relationships are used in the model: (a) the dynamics of forage consumption; (b) the dynamics of energy gain and loss in animals; (c) the effects of energy balance on the ability to reproduce and survive; and (d) a simple population model which accounts for age-specific reproduction, hunting, and survival rates within a population. These general relationships and the species-specific values describing the relationships are discussed later.

The model is not a simulation model *per se*. The user does not examine predicted changes in ungulate populations over time in response to changing management activities. Rather, the model calculates the number of animals which the environment can support; the user can define this environment in any desired manner (Figure 4). The factors defining the environmental conditions are assumed constant for that particular run of the model. By assuming constant environmental conditions for the species of interest, the model simply needs to calculate the carrying capacity of the environment as defined by the user. Because the functional relationships in the model are complex and cannot be solved analytically, the model is initialized with a very low ungulate population. The population is then allowed to grow, according to the rules described in the functional relationships, until it has stabilized, usually after about 20 years. The level at which it stabilizes is the carrying capacity. Therefore, the user is only able to discover the consequences of alternate sets of environmental conditions for ungulate carrying capacity.

Bounds of the model

Any model cannot include all factors and components which might be important. Such a model would be too cumbersome to use because it would be impossible to deduce the mechanisms by which a particular set of environmental conditions gave rise to observed model behaviours. It is therefore critically important to bound the

model by defining and including in the model those components which really have a major influence on ungulate populations and to make note of those which have been explicitly excluded. The major steps in bounding a model are (a) definition of management indicators which will be produced by the model, (c) definition of model spatial extent and resolution, (d) definition of time horizon and step, and (e) definition of driving variables.

Management actions — Three sets of management actions are included in this model (a) habitat manipulation, (b) ungulate harvest, and (c) secondary effects of development activities. This refers to factors such as ungulate disturbance from noise sources and human activity other than hunting.

Management indicators — The status of the ungulate population is the only system component which is of concern in this model. Therefore, the only indicators produced by the model pertain to the health of the population. The management indicators produced by the model are (a) total ungulate population, (b) total ungulate harvest, (c) young to adult female population ratio, and (d) distribution of the ungulate population among the different habitats. The values of these model variables are produced by the model and printed on the computer monitor at the end of the model run.

Space — Both spatial resolution and extent must be defined when bounding the model.

i) Spatial resolution

The model considers six habitat types; their names and the ungulate species which use them are given in Table 4. Each type is subdivided into four forest canopy cover classes (no cover, low cover, medium cover, and high cover) and four stand maturity classes (clearcut, immature, mature, and overmature). This provides a total of 96 separate habitat types. The model does not keep track of the explicit relationship between spatial units so all land area in each of these 96 habitat types in the region of interest is summed. Also, although there are 96 potential habitat types, the number of habitat types that will actually be present in a region of interest for an ungulate species of interest is likely to be smaller, as each species only uses a few of the habitat types and only some of the cover classes. Stand maturity classes do not exist for some of the habitat types (i.e. Alpine habitat is unlikely to have high forest cover).

Table 4. Habitat types simulated in the model

Habitat types	Used by
Alpine	Elk, deer
Montane forest	Elk, deer, moose
Upland forest	Elk, deer, moose
Lowland forest	Elk, deer, moose
Alluvial complex	Elk, deer, moose
Unusable	None

The user can implement alternate management scenarios on this structure by changing the areas of land in each habitat type. This way, the mechanism by which the habitat is altered (thinning, clearcutting, burning, etc.) does not have to be specified but can be changed externally in a model gaming environment.

ii) Spatial extent

Because the model will be applied to many specific areas in British Columbia, the spatial extent varies with the specific region being considered and the ungulate species being modelled, the spatial extent cannot be defined beforehand. Therefore, the spatial extent is simply defined as the sum of the areas in all of the habitat types for the region of interest.

Time — The model simulates population change in the ungulate species for 20 years in order to calculate the carrying capacity of the environment for the ungulate species of interest. Only the winter season is simulated as the period of the year in which most of the environmental limitations are likely to occur. The winter season is set to 165 days in length: November 1 to April 15.

An opportunity is provided to examine the consequences of limiting summer ranges in the model by changing the energy status of the ungulate population as it enters the winter season.

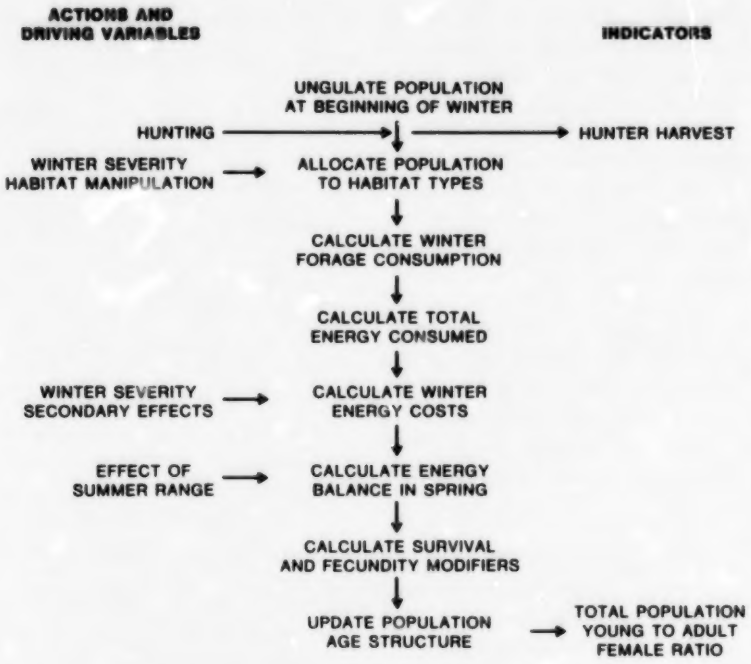

ACTIONS AND DRIVING VARIABLES
INDICATORS
UNGULATE POPULATION AT BEGINNING OF WINTER
HUNTING
HUNTER HARVEST
WINTER SEVERITY HABITAT MANIPULATION
ALLOCATE POPULATION TO HABITAT TYPES
CALCULATE WINTER FORAGE CONSUMPTION
CALCULATE TOTAL ENERGY CONSUMED
WINTER SEVERITY SECONDARY EFFECTS
CALCULATE WINTER ENERGY COSTS
EFFECT OF SUMMER RANGE
CALCULATE ENERGY BALANCE IN SPRING
CALCULATE SURVIVAL AND FECUNDITY MODIFIERS
UPDATE POPULATION AGE STRUCTURE
TOTAL POPULATION YOUNG TO ADULT FEMALE RATIO

Figure 5. Order of calculations in the model.

Driving variables — A driving variable is a factor which influences the dynamics of the system of interest, but is not, itself, influenced by the system. Climatic factors are generally considered to be driving variables of biological systems.

It is well accepted that winter severity, primarily snowfall, can have extreme consequences for ungulate populations. The model considers four classes of winter severity. These are represented by different levels of snowfall: no, low, medium, and high. These qualitative descriptions of snowfall levels are defined in terms of their effects on the animal, so that a high snowfall for a small ungulate such as deer, is a medium or low snowfall for a large ungulate such as moose.

Model functional relationships

The order of calculations in the model for a single year is described in Figure 5. Only the winter period is simulated each year; animal harvest occurs at the beginning of each winter. The population is then allocated to each habitat type which is present. Once on each habitat type, the population feeds and ingests energy. The energy costs during the winter are then calculated, based on effects of snow and secondary development. The energy balance is used to calculate fecundity and survival multipliers which are then used at the end of the winter period to update the population. The population at the end of the winter period then becomes the population at the beginning of the succeeding winter period. This annual simulation continues for 20 years, whereupon the final indicators are computed.

Characterization of populations — All ungulate species which can be simulated in the model are characterized by four age and sex classes: (a) age 0 males, (b) age 0 females, (c) adult males, and (d) adult females. A larger number of age classes would be desirable if the model were a simulation model; this would make age-structure perturbations more apparent. However, this is not a strict simulation model, and, as age-specific parameters would likely be very similar for all adult age classes, the population is represented by only two age classes.

It is assumed that males will be able to impreg-

nate all females irrespective of the male to female ratio in the population.

Fecundity and survival multipliers — Each ungulate species has a maximum fecundity rate specific to each age class (Figure 6a). This rate is modified by relationships which relate to the change in energetic status of the animal through the winter period (Figure 6b). The parameter sets describing this relationship indicate that large ungulates (elk and moose) are more sensitive to winter weight loss than small ungulates (deer) when the effects are manifested as a fecundity reduction, but that small ungulates are more sensitive to winter weight loss than large ungulates when the effects are manifested as starvation.

Winter weight loss — The winter weight loss, as a function (i.e. percent) of a maximum summer weight, is calculated by:

$$WL_i = \frac{WC_i}{MSW_i} \times 100 \qquad (1)$$

where,

WL_i = winter weight loss for age and sex class i as a proportion of maximum summer weight;
MSW_i = maximum summer weight (kg); and
WC_i = weight change over winter (kg).

Each age and sex class for each ungulate species is assigned a maximum summer weight (Table 5). A yearling weight is used for the young of the year classes as this age class is approximately 1 year old at the end of its first winter.

The change in weight over the winter period is calculated by:

$$WC_i = \frac{EI_i - EC_i}{6000} \qquad (2)$$

where,

EI_i = energy intake over the winter period (kcal);
EC_i = energy costs over the winter period (kcal); and
6000 = the kcal of energy per kg of fat.

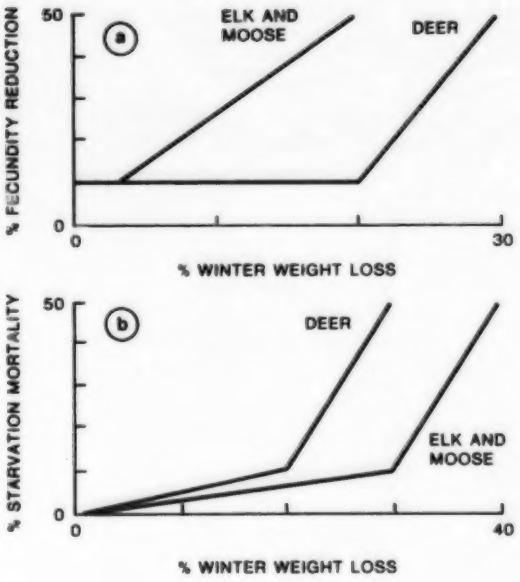


Figure 6. Effect of winter weight loss on (a) fecundity reduction and (b) starvation mortality: i) elk and moose; and ii) deer.

The functional relationships in the model which compute energy intake and energy costs are described in the sections below. The energy in fat reserves at the start of the winter season is calculated by:

$$ES_i = 6000 \times MSW_i \times PF_i \times PC_i \qquad (3)$$

where,

PF_i = maximum proportion of summer weight in body fat (Table 5); and

PC_i = proportion of maximum body fat realized over the summer.

PC can be used to examine effects of decreasing summer habitat. Normally, this is set to 1.0. Lower values will reflect how well the species was able to store energy over the summer period and, therefore, the effects of summer habitat manipulation.

Winter Energy Costs - Moen (1973) describes a general equation for calculating the winter metabolic costs, in kcal, of a single ungulate by:

Table 5. Maximum fecundities, summer weights, and maximum fat content

Species	Age and sex class	Maximum fecundity	Weight (kg)	Fat content (%)
Deer	Male fawn	–	27	12
	Female fawn	0.8	27	12
	Buck	–	130	15
	Doe	1.6	115	15
Elk	Male calf	–	80	12
	Female calf	0.7	80	12
	Bull	–	240	18
	Cow	1.4	190	18
Moose	Male calf	–	95	12
	Female calf	0.65	95	12
	Bull	–	280	18
	Cow	1.3	220	18

$$D \times AMM \times BMR \qquad (4)$$

where,

D = the number of days in the winter season (set to 165);
AMM = the active metabolic multiplier (varies seasonally); and
BMR = basal metabolic rate, set to 70 kcal/kg of maximum summer weight raised to the power of 0.75.

In this model, equation (4) is modified to account for secondary effects, such as snowmobiles and general harassment, and different snow conditions as shown by:

$$EC_i = D \times PM \times AMM_k \times BMR \qquad (5)$$

where,

PM = a variable which can be modified to account for harassment effects; and
AMM_k = active metabolic multiplier for snowfall Class k.

The values for the active metabolic multipliers used in the model are shown in Table 6. These values are used for all species because the severity of the snowfall and the winter season is defined relative to the tolerance of the ungulate species.

Example relationships of energy costs to weight are shown in Figure 7. This figure clearly shows that the energetic costs per unit weight decrease with increasing body weight (decreasing slope on the curves) and that heavy snowfalls and harassment greatly increase the energy costs to the species.

Winter energy intake — At its simplest level, the winter energy intake for a single animal of (age and sex) class i is represented by:

$$EI_i = \sum_{s=1}^{n} \sum_{j=1}^{3} BI_{i,j,s} EV_j \qquad (6)$$

Table 6. Active metabolic multipliers for different snow conditions

Snowfall	Active metabolic multiplier
No	2.0
Low	2.0
Medium	2.5
High	3.0

where,

EI_i = total energy consumed;
$BI_{i,j,s}$ = biomass of forage type j consumed on habitat type s (kg); and
EV_j = energy content of forage type j (kcal/kg).

The forage contents are given in Table 7.

Forage consumption — Forage consumption has traditionally been difficult to simulate simply because there are innumerable factors which operate to influence how much forage is consumed. Factors such as abundance, preference, palatability, and digestibility affect forage consumption. A number of procedures exist for integrating these factors. The functional relationships used in this model have been extracted from general predation theory which has been well tested in laboratory and field experimentation and shown to be a good method of integrating these factors into predicting forage consumption (Holling 1959; Charnov 1973; Mace et al. 1979).

The general equation is for a single forage type and is represented by:

$$BI = \frac{a \times D \times F}{1 + a \times h \times F} \qquad (7)$$

where,

D = the number of days in the winter season (set to 165);
a = the effective search rate (ha/day);
F = the forage biomass (kg/ha); and
h = the handling time (day/kg).

Examples of equation (7) are presented in Figure 8.

Table 7. Forage energy contents

Forage type	Metabolized energy content (kcal/kg)
Forbs	2295
Shrubs	1530
Conifers	1530

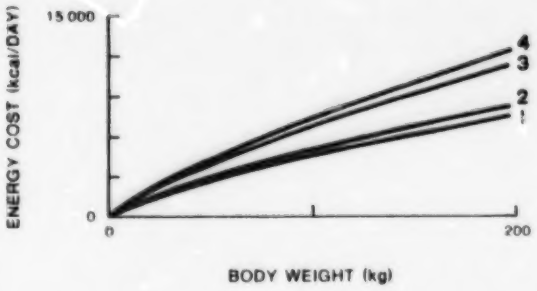


Figure 7. Effect of snowfall and secondary disturbance on energy costs: (1) low and medium snowfall, no secondary disturbance; (2) low and medium snowfall with additional 10% energy cost from secondary disturbance; (3) heavy snowfall, no secondary disturbance; and (4) heavy snowfall with additional 10% energy cost from secondary disturbance.

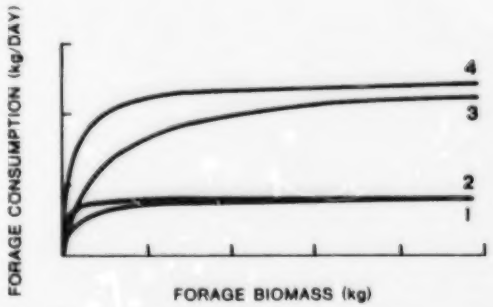


Figure 8. Forage intake model: (1) high handling time, low search rate; (2) high handling time, high search rate; (3) low handling time, low search rate; and (4) low handling time, high search rate.

The roles of its parameters are intuitively easy to grasp. The handling time h is simply the inverse of the maximum daily forage intake rate and reflects how much forage an ungulate could consume if it did not have to search. Moen (1973) states this is between 2% and 5% of body weight per day; the model uses a value of 5% of body weight per day. Effective search rate, a, is more difficult to estimate but it is a measure of the animal's ability to find forage when forage is at low densities. It has been set to 2.5 ha per day for small ungulates (deer) and 10 ha per day for large ungulates (elk and moose).

The model uses an expansion of equation (7) to account for different biomass among different forage types and different levels of habitat use. The biomass of forage type j consumed on habitat type s by ungulate class i is calculated by:

$$BI_{i,j,k} = \frac{a \times P_j \times D \times F_{j,s}}{1 + a \sum_{j=1}^{3} P_j \times F_{j,s}} \qquad (8)$$

where, P_j = preference for forage type. Equation (8) calculates what the forage consumption would be without intraspecific competition. Because forage must, at some point, become limiting to ungulate populations, the actual forage consumption is simply prorated across all ungulate classes as shown by:

$$BI_{i,j,s} = \frac{U_{i,s} \times BI_{i,j,s}}{\sum_{i=1}^{v} U_{i,s} \times BI_{i,j,s}} \qquad (9)$$

where,

$U_{i,s}$ = the number of ungulates per ha in habitat type s.

Allocation to habitat types — Habitat selection processes in ungulate populations are poorly understood. Wildlife biologists recognize that factors such as forage, escape cover, thermal cover, and snow cover regulate ungulate distributions (e.g. Thomas 1979), but no predictive models have yet been constructed which mimic and explain changes in ungulate distribution in response to different environmental conditions.

Rather than construct such a complicated model of ungulate habitat selection, a simple representation is used. The ungulate density on a habitat type is assumed to be directly proportional to the relative value of that habitat type as shown by:

$$U_{i,s} = \frac{TU_i \times HV_s}{TV} \qquad (10)$$

where,

HV_s = the habitat value of habitat type s;
TU_i = the total number of ungulates in class i; and
TV = the total habitat value for all available habitat types.

The habitat value of a particular habitat type is a function of its available forage levels, total area, and physical habitat modifier as given by:

$$HV_s = AR_s \times PH_{s,k} \times \sum_{j=1}^{3} F_{j,s} \qquad (11)$$

where,

AR_s = the total area of habitat type s; and
$PH_{s,k}$ = the physical modifier index for habitat type s for snowfall class k.

The physical modifier index is intended to aggregate all other factors such as slope, aspect, elevation, and cover value. Its value is allowed to explicitly change under different snowfall conditions.

Harvest — A user-defined and ungulate class-specific harvest rate is applied to the population at the start of the winter season.

Model Documentation

The relationships and parameters for this model have been derived from a wide variety of literature sources; a summary of the documentation is provided in Table 8.

Some of the relationships are based on the professional judgements of wildlife biologists. This is to be expected, as populations and their environment are presently poorly understood. However, this should not limit the utility of this model, as management decisions are continually being made in the face of this uncertainty. When other information is unavailable, it is better to use the judgement of informed research scientists about important relationships or parameters in evaluating management strategies.

The professional judgements come from wildlife biologists who have participated in a large number of modelling workshops on the population dynamics of ungulates and their responses to habitat manipulation (McNamee et al. 1981; 1982; Bunnel et al. 1983; McNamee et al. 1984a;

McNamee et al. 1984b). These scientists have come from the following agencies and institutions: British Columbia Ministry of Forests; British Columbia Ministry of Environment; University of British Columbia; Wyoming Department of Fish and Game; Alaska Department of Fish and Game; U.S. Forest Service; U.S. Fish and Wildlife Service; and Colorado Division of Wildlife.

The effect of changing a parameter or relationship in the model is presented graphically in Figure 9; a parameter or relationship can influence model predictions in one of two ways. A parameter such as survival rate scales the carrying capacity (Figure 9a), while a parameter such as handling time will alter the sensitivity of the population to a changing environment (Figure 9b). Table 8 gives the effect each parameter or relationship has on the prediction of carrying capacity in the model.

Applications of the model

This type of model will never be able to provide precise quantitative predictions about the effects of habitat manipulation and hunter harvest on ungulate populations, nor should it be used for that purpose. It would be foolish to assume such a model could be built and dangerous to interpret the results of this model with that intent. The understanding of the interactions and dynamics of ungulate populations will never be perfect or complete. It is important, however, to strive for a model which captures the essential qualitative behaviour of the ungulate population in response to *alternate habitat management strategies*. The importance of this concept of model use is critical. The relationships contained in this model have been derived from current data and hypotheses pertaining to the response of ungulate populations to their environment. In that sense, it can be regarded as a good synthesis of current understanding. Ideally, this model should be modified and updated as future research results become available.

This implies that the model should not be run only once with the user regarding the results of the model run as what will actually occur given the environment he or she has defined. Instead, the model should be gamed with extensively. The user should regard the model as a kind of

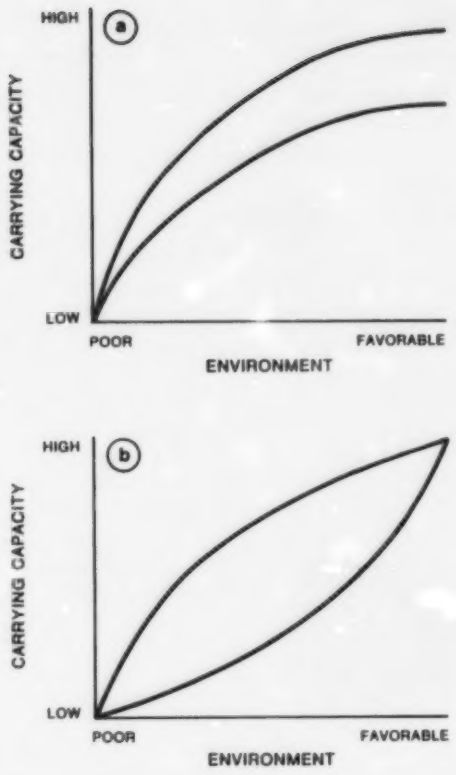


Figure 9. Two effects of varying model parameters and relationships: (a) scaling effect, where different parameter values or relationships scale the carrying capacity up or down, and (b) sensitivity effect, where different parameter values or relationships alter the sensitivity of the population to different environments.

"laboratory world," where the effects of a wide range of management strategies can be examined without attempting them in the real world. This way, the user can gain insight into how ungulate populations will likely fare under a given management regime, relative to how they will likely fare under other management regimes.

Results and discussion

Sustainable ungulate populations

Based on the materials and information discussed in the first part of this report, sustainable cervid

Table 8. Model documentation

Process/parameter	Source	Comments	Effect on prediction of carrying capacity*
Reduction in fecundity from winter weight loss	Professional judgement; Bunnell et al. 1983	Derived from unpublished data on penned experiments by the Colorado Division of Wildlife	Scaler
Reduction in survival from winter weight loss	Professional judgement Bunnell et al. 1983	Derived from unpublished data on penned experiments by the Colorado Division of Wildlife	Scaler
Animal weights	From hunting record files in B.C. Fish and Wildlife, Cranbrook	Males were assumed 25% heavier than females	Changes sensitivity of population to changing environment
Maximum fat content	Professional judgement Bunnell et al. 1983	Derived from unpublished data on penned experiments by the Colorado Division of Wildlife	Changes sensitivity of population to changing environment
Active metabolic multiplier	Professional judgement; Mattfield 1974; Bunnell et al. 1983; Parker 1983; McNamee et al. 1984a; McNamee et al. 1984b Wickstrom, in press	Derived from estimates made by Colorado Division of Wildlife biologist and Alaska Department of Fish and Game biologists	Changes sensitivity of population to changing environment
Length of winter season	Professional judgement	Effects of different season lengths are manifested in active metabolic multipliers	Scaler
Forage energy content	Rochelle 1980; McNamee et al. 1981; McNamee 1982; Hanley and McKendrick 1983		Scaler
Foraging search rates	Professional judgement; Wickstrom, in press; Waiters and Bunnell 1971	Estimated using information of foraging time and locomotion rates	Changes sensitivity of population to changing environment
Handling time	Moen 1973; Bunnell et al. 1983; McNamee et al. 1984a; McNamee et al. 1984b	The inverse of maximum daily intake	Changes sensitivity of population to changing environment

Table 8. (Cont'd)

Process/parameter	Source	Comments	Effect on prediction of carrying capacity*
Maximum birth rates	Professional judgement from hunting record files in B.C. Fish and Wildlife, Cranbrook	Young to adult female ratios in hunting statistics were doubled and it was assumed that fecundity in young of year is 50% in adult females	Scaler
Baseline survivals	Estimated from ONEPOP (Gross et al. 1973); professional judgement		Scaler
Range productivity	Professional judgement; TAESCO 1985c; Schuerholz 1982; B.C. Fish and Wildlife, Cranbrook	Productivity rates were changed arbitrarily with changing canopies, age classes and site indices	Changes sensitivity of population to changing environment

populations were calculated by species for three different snowfall classes, current forest cover, and expected forest cover change due to salvage logging of beetle-killed pine in the White River area.

Snowfall is a principal limiting factor to cervids, and categories of snowfall have been arbitrarily defined for this project as shown in Table 9. Supporting data for this classification were provided by Telfer (1978) for moose and deer, by Schuerholz (1982) and TAESCO (1985b) for elk, and by Poelker (1972) for moose. Snowfall categories are described by snow depth only. In the following sections, changing categories due to snow density will be discussed by species and for different forest canopy conditions together with sustainable populations.

Sustainable population data are calculated *without harvest* of animals.

The White River study area supports good populations of elk, mule deer, white-tailed deer and moose.

Large areas of beetle-damaged lodgepole pine have been salvage-logged over the past two decades in the lowland and upland forests of the White River study area. Homogeneous stands have been clear-cut, and the mixed stands selectively utilized, creating an expansive mosaic of large openings with semi-open stands of western larch and Douglas-fir and closed stands of immature lodgepole pine. Following logging, seral grasses and shrub-dominated plant associations formed the new vegetation cover with excellent forage conditions for wintering cervids. Adjacent stands of western larch, Douglas-fir, and

Table 9. Depths (cm) of snow which constitute low, medium, and heavy snowfall for moose, elk, and deer. These categories were used in calculating sustainable population.

	Category		
Species	Low	Medium	Heavy
Moose	0-40	40-60	>60
Elk	0-30	30-50	>50
Deer	0-20	20-40	>40

lodgepole pine provide both hiding and thermal cover for elk and deer. This combination of food and shelter has created a major cervid winter range where only a minor range existed before logging.

Although large areas in the montane forest habitats are beetle-damaged, salvage logging has not progressed as rapidly as in the more accessible lowland areas. In clearcuts with seral grass-shrub communities, utilization is heavy by deer, elk, and moose, particularly in areas interspersed with good quality thermal and hiding cover. Moose occupy the young stands as soon as conifers provide hiding cover (i.e., as soon as they reach 3 m in height). Elk and deer persist in the openings of the Montane habitat until snow depth exceeds 50 cm, before moving to the low snowfall winter ranges. Moose may be found throughout the winter if snow conditions permit. With increasing snow depth, moose move upslope (Poelker 1972; Demarchi et al. 1984).

Although the seral shrub-grass stage is relatively short (1 to 15 years) it provides cervids with high quality forage in summer, enabling populations to grow.

From experience with salvage logging of beetle-killed lodgepole pine in the White River study area, it may be assumed that the programmed salvage operations continue to benefit forest dependent cervids if sufficient thermal cover in low and medium snowfall areas is provided. Current logging prescriptions in the White River watershed are outstanding in British Columbia in that they create high-quality cervid range.

Table 10 shows sustainable elk populations before and after salvage logging. As explained in the description of the model, only winter ranges are considered for the "total area" composed of usable and unusable habitat. Corresponding summer range is expressed as the sum of physical modifiers which reflect the condition of a population at the onset of winter. For the White River study area, it is assumed that the cervid populations do not suffer habitat constraints in summer and enter the winter in prime physical condition. Range productivity data were extrapolated from available information on the upper Elk River valley (TAESCO 1985b) which has the same climate region and comparable biogeoclimatic zones and subzones.

The results for sustainable elk population show that without snow, elk seem to prefer the young seral grass-shrub communities offered mostly in the lowland habitats as a result of clearcut and selective salvage logging (Table 10). Under con-

Table 10. Elk winter habitat and estimated sustainable populations of elk in the White River study area before and after salvage logging

Snowfall	Habitat area (ha)			Sustainable population	Y:AF[a] ratio	Habitat use (%)		
	Usable	Nonusable	Total			Alpine	Lowland	Upland
	Before salvage logging							
No	5761	224	5985	1076	0.66	0	55.9	44.1
Low	5761	224	5985	621	0.65	0	60.6	39.4
Medium	5761	224	5985	287	0.54	0	53.8	46.2
Heavy	5761	224	5985	37	0.26	0	36.1	63.9
	After salvage logging							
No	5829	224	6053	1184	0.66	0	52.9	47.1
Low	5829	224	6053	690	0.65	0	59.2	40.8
Medium	5829	224	6053	329	0.54	0	51.5	48.5

[a] Young: adult female

ditions of no snowfall, approximately 44% upland habitat versus 56% lowland habitat is utilized. Elk are not found on alpine range during winter. With low snowfall, dormant vegetation in the herb layer and low growing shrubs are still accessible in the lowland habitat which also provides for easier movements (i.e. lack of steep slopes). As a result, elk make high use of the lowland areas (i.e. 60% lowland versus 40% upland). If snow persists for an extended time period, the sustainable population decreases by 43%. From medium snowfall to heavy snowfall, the population decline is dramatic. Heavy snowfall implies a long duration of snow over 50 cm, covered by a hard crust, restricting forage to emerging shrubs. With medium and heavy snow, elk make increasing use of mature, closed-canopy forests. Such stands provide the animals with thermal shelter, facilitate their movements (i.e. supporting crust on densely packed snow), and offer additional forage through litter fall. These conditions on the White River elk winter range are mostly offered in the upland forests since most of the accessible lowland forests have been salvage-logged. The shift in habitat use with increasing snow depth is shown in Table 10. Upland habitats receive 7% more use with medium snowfall than with low snowfall, but 24% higher use with heavy snowfall.

The same general habitat use pattern emerges for elk on the winter range after changes in habitat composition as a result of the salvage logging over the next 10 years.

This use pattern implies that most of the stands to be salvage-logged are still located in the lowland habitat.

The results indicate that salvage logging will result in increasing sustainable elk populations due to the expected increase in forage production within the shrub-herb layers (Figure 10). This increase, however, is only possible with a continuation of the currently practiced logging prescription, which provides good quality edge zones and leaves sufficient thermal cover.

Both white-tailed and mule deer occur in the study area. Mule deer more than white-tailed deer are associated with elk due to similar feeding habits and habitat preferences. White-tailed deer are principally lowland occupants, frequently associated with agricultural activities in the river floodplain and adjacent foothills. Mule deer and

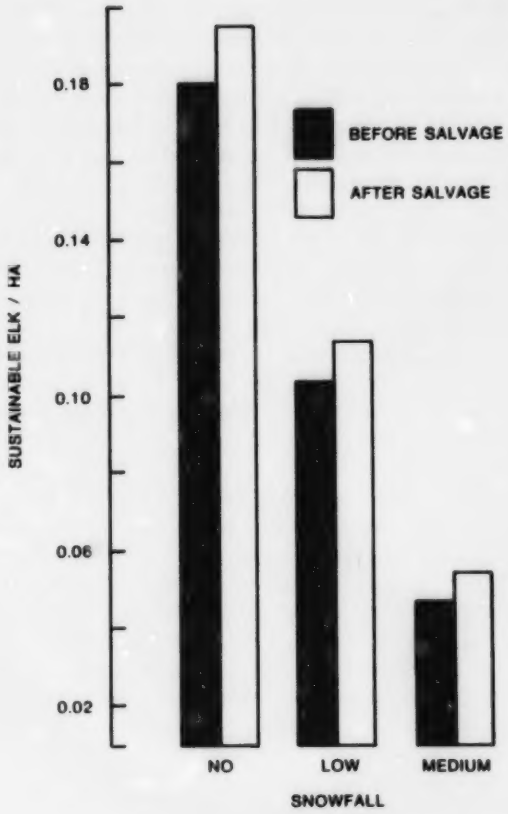


Figure 10. Sustainable elk population for the White River study area before and after salvage logging of beetle-infested lodgepole pine.

elk are upland occupants which depend upon shrub communities at the lower and mid-montane positions. Only during severe winters do the ranges of both deer species overlap. For convenience, in this report both deer species are combined.

Mule deer, white-tailed deer, and elk are sympatric species on the White River range. Competitive exclusion between elk and mule deer may occur and will be more pronounced under adverse snow conditions.

When comparing sustainable deer and elk populations on the same winter range, it becomes apparent that with increasing snow depth, deer have the disadvantage. Although the decrease in

sustainable populations from "no" to low snowfall is alike for both species, the drop in population resulting from an increase from low to heavy snowfall is distinctly higher for deer than for elk (Table 11). Deep and soft snow is detrimental to the deer fawns. It affects elk calves less significantly as shown by the corresponding *young: adult female* ratios; with heavy snowfall, no deer fawns survive (Table 11), whereas under the same conditions 45% calf elk survive (Table 10). This shows that deer are much more dependent on mature forests with heavy canopy. Snow under dense forest canopy is generally more compact and able to support deer. Litterfall under such conditions may contribute significantly to the food supply.

When comparing habitat use by deer for the current forest cover situation with expected changes following salvage logging, it becomes apparent that the general habitat use pattern remains the same (Table 11). Deer still prefer the nutritious forage offered through early seral communities in the lowland habitat until forced by snow into the upland forests, the same pattern as described for elk.

The comparison of sustainable populations before and after logging indicates that, although an overall larger deer population can be supported after logging with medium snowfall, the *young: adult female* ratio will decrease by 66%. This may indicate that after salvage logging, less mature forest area, needed particularly by deer fawns as climatic shelter, may be available.

The overall comparison of sustainable deer population before and after salvage logging shows that logging will enhance deer winter range (Figure 11).

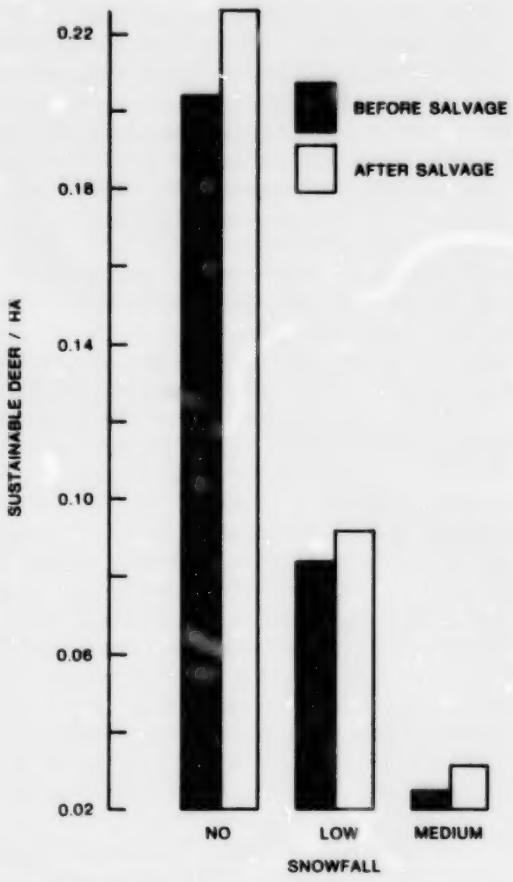


Figure 11. Sustainable deer population for the White River study area before and after salvage logging of beetle-infested lodgepole pine.

Moose in the White River study area are closely linked to upland forests and montane habitat with southern exposure. Snow depth is considerably less limiting to moose than to elk or deer. The long-legged moose is well adapted to deep snow and will survive on a twig and branch diet for several months. The difference in habitat use and feeding behaviour between moose and elk will generally prevent competitive exclusion.

According to available information, moose on the White River winter range seem to spend 100% of their time in upland forests (Table 12). The upland forest category also includes montane habitats with southern aspect.

The salvage logging of beetle-killed pine would increase the usable moose winter range by 51%. Although this would cause an overall increase in the moose population, it would not increase the range quality *per se*. The carrying capacity per hectare would remain approximately the same.

The increased moose population following salvage logging would be less affected by a year of heavy snowfall than it would have been before logging, since more calves would survive. Overall, this would produce a more productive herd which would be able to recover more quickly than the herd before the habitat expansion.

Table 11. Deer winter habitat and estimated sustainable populations of deer in the White River study area before and after salvage logging

Snowfall	Habitat area (ha)			Sustainable population	Y:AF[a] ratio	Habitat use (%)		
	Usable	Nonusable	Total			Alpine	Lowland	Upland
	Before salvage logging							
No	5761	224	5985	1223	0.62	0	55.0	44.1
Low	5761	224	5985	503	0.37	0	57.8	42.2
Medium	5761	224	5985	149	0.34	0	47.5	52.5
Heavy	5761	224	5985	13	0	0	37.2	62.8
	After salvage logging							
No	5829	224	6053	1369	0.63	0	53.0	47.0
Low	5829	224	6053	559	0.38	0	55.0	45.0
Medium	5829	224	6053	195	0.36	0	48.2	51.8

[a] Young: adult female

Table 12. Moose winter habitat and estimated sustainable populations of moose in the White River study area before and after salvage logging.

Snowfall	Habitat area (ha)			Sustainable population	Y:AF[a] ratio	Habitat use (%)		
	Usable	Nonusable	Total			Alluvial	Lowland	Upland
	Before salvage logging							
No	4428	105	4533	972	0.66	0	0	100
Low	4428	105	4533	576	0.66	0	0	100
Medium	4428	105	4533	267	0.61	0	0	100
Heavy	4428	105	4533	48	0.30	0	0	100
	After salvage logging							
No	6681	105	6786	1462	0.66	0	0	100
Low	6681	105	6786	868	0.66	0	0	100
Medium	6681	105	6786	404	0.61	0	0	100
Heavy	6681	105	6786	71	0.48	0	0	100

[a] Young: adult female

With heavy snowfall, the *young: adult female* ratio is more than 60% higher after salvage logging than before. The general comparison of sustainable moose populations before and after salvage logging clearly indicates that salvage logging does not increase the carrying capacity on a per hectare basis (Figure 12).

In conclusion, salvage logging of beetle-killed lodgepole pine in the White River study area will enhance habitat for all cervid species and will expand the winter range. This will result in increasing populations providing more options for management.

Cervid management in the East Kootenays

The following sections are a brief overview of the history of cervid management in the Kootenay region and of expected changes in management strategies in response to salvage logging of beetle killed pine forests.

From 1960 to the early 1970s, serious land use problems combined with liberal hunting regulations caused an alarming decline in elk populations in the East Kootenays. Overgrazing of elk winter ranges by domestic stock, land alienation, and forest encroachment were the principal problems. A pulp mill was constructed on prime elk winter range at Skookumchuk and timber harvesting was increased. Access was expanded into remote areas, gradually increasing hunting pressure and harassment of wintering populations. Elk populations were low, winter ranges were in a deplorable condition, and resource use conflicts were mounting. Range management was careless, timber management was misunderstood, and politicians would not address the problems.

By the early 1970s, the management of cervids was based on better scientific insight. As a result of improved management and improved working relationships with other resource agencies, the elk population increased from 4950 animals in 1970 to 7850 in 1974. The land use conflicts finally led to the introduction of coordinated resource management planning, a procedure which involved resource managers and users in a collective decision-making capacity. Forage was managed by the British Columbia Ministry of Forests, Range Division, but wildlife was considered as well as livestock. Deferred rotational grazing systems were introduced which led to more efficient use of forage by both wild and domestic ungulates.

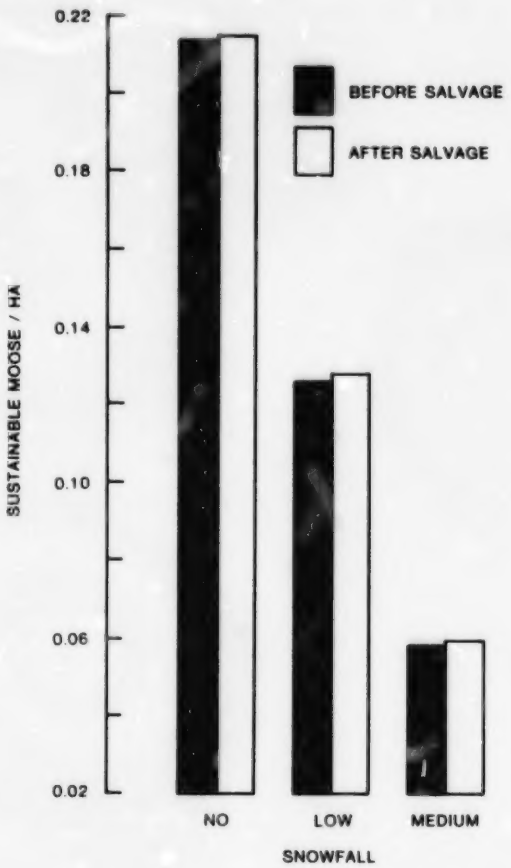


Figure 12. Sustainable moose population for the White River study area before and after salvage logging of beetle-infested lodgepole pine.

By the mid-1970s, vast areas of mature lodgepole pine forests were being salvage logged by local timber companies following an outbreak of mountain pine beetle (*Dendroctonus ponderosae* (Hopkins)). Most of the logging occurred at lower and middle elevations in the IDF, MS and ESSF biogeoclimatic zones. Following the logging, seral shrubs and grass communities thrived.

The combination of improved range and habitat creation by timber harvest had a dramatic effect on cervids, particularly elk. For the first time in

at least two decades, expansion of the East Kootenay elk herds became possible because food was being produced for the animals as a by-product of industrial activity.

The increase in elk populations in response to good management and excellent cooperation between industry and resource agencies in the East Kootenays provide a current elk harvest of 5000 animals. The East Kootenay elk population was estimated at 22 000 animals in 1985.

The prognosis for the next decade is that good forest and range management will continue to improve elk habitat throughout most of the elk winter ranges. Access management combined with improved allocations made under the limited entry system should ensure sustained use of existing elk herds.

If range burning is expanded in and adjacent to the Rocky Mountain Trench, fire dependent shrubs and grasses should thrive. Similarly, seral shrubs and grasses will be created through logging, enhancing elk food supply on summer and winter ranges. These habitat enhancements will enable the population to increase to an expected level of 30 000 elk by 1990.

Although deer and elk management should be closely related, the history of deer management in the East Kootenays is much less defined than for elk. Firstly, both white-tailed deer and mule deer are combined in British Columbia's hunter return statistics preventing the use of the statistics for the definition of species-specific harvest strategies. Secondly, deer in the East Kootenays always were considered to be abundant; consequently, management concentrated on population reduction only.

A brief assessment of deer population history in the area of interest shows that widespread fires in the 1930s created vast areas of deer habitat throughout the Kootenays. Deer populations increased exponentially until the early 1960s when overgrazing by livestock and wild ungulates led to the deterioration of most shrublands which provide the major deer winter ranges in the region. The exclusion of wildfire from these areas aggravated the situation; overmature shrubs turned decadent, providing increasingly less forage to deer. *Ceonothus velutinus*, *C. arguineus*, *Purshia tridentata*, and *Amelanchier alnifolia* are important food sources for deer. (The growth of these shrubs is stimulated by fire which causes quick rejuvenation.)

Deer populations continued to decrease in response to accelerated range deterioration and excessive harvest from the mid-1960s to the mid-1970s.

Within the last decade a concerted effort has been made to enhance deer ranges and design better management strategies. Logging in the Rocky Mountain Trench and adjacent areas has improved some ranges and adversely affected others. In the White River study area, salvage logging of beetle-killed pine stands had an overall positive impact on deer winter range.

Prescribed fire and logging will enhance habitats and revitalize important winter ranges; with increasing quantity and quality of forage, populations will increase.

Very little is known about the history of moose populations in the Kootenays. Moose never seem to have occurred in large densities. Herd sizes seem to fluctuate in response to changing environments. The current combined moose population of the East and West Kootenays is approximately 5000 animals, of which less than 300 are recorded for the West Kootenays.

It is generally accepted that timber harvest in low to moderate snowfall areas is beneficial to moose by creating seral grass-shrublands subsequent to logging and burning. The salvage of beetle-killed pine in the trench has expanded moose winter range.

In conclusion, the expected increase in salvage logging will be most beneficial to elk and deer and will also benefit moose.

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